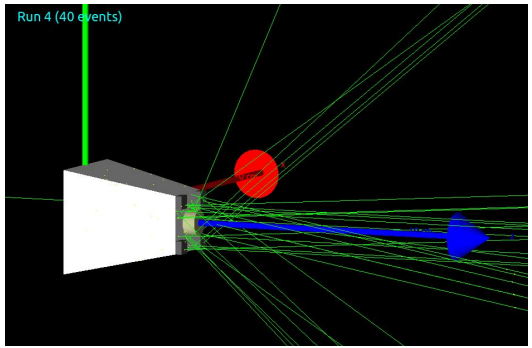
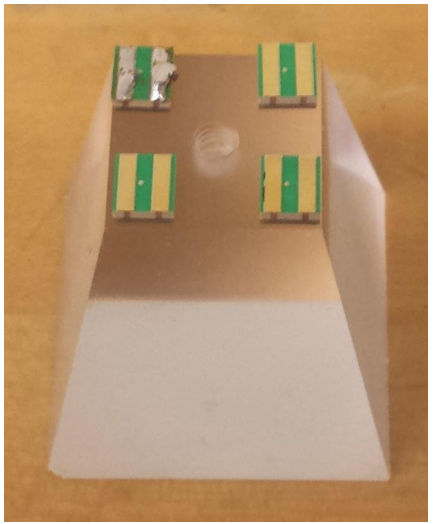


Geant4 Study of Lightguide Efficiency/ Uniformity



Michael Phipps, Simon Li, Anne Sickles

Method

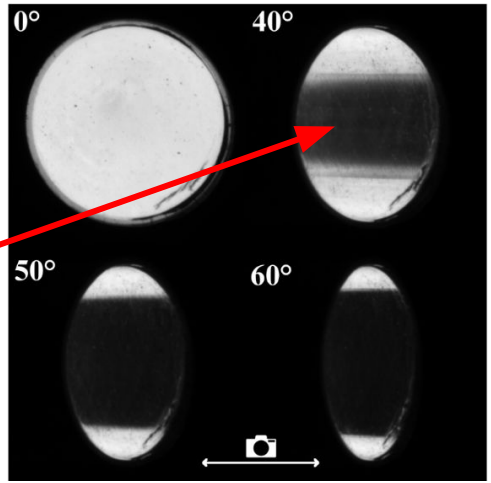
- Geant4 scan using 2.75 eV photons
- Scan proceeds in steps of 0.36 cm with 1k events per position and a 64 x 64 sample matrix
- Total efficiency defined as average hits/samples across entire scan
- Hit defined as any event with a photon entering an sipm. Hit receives a score of 1, all other events receive a 0
- Lightguide built with acrylic and refractive index of 1.60, absorption length of 5.4 m and emission index of 11.0 (as defined for PMMA in geant WLS example)
- Screw built with stainless steel and given refractive index of 2.757, absorption length of 3.6 um and emission index of 11.0 (same as acrylic -- only parameter I couldn't find)
- Boundary between lightguide defined as dielectric-metal with unpolished surface
- Four 3x3 mm sipms flush against end of lightguide
- Outside volume defined as air with a polished dielectric-dielectric boundary between air and lightguide.

Angular Distribution

- Particle gun placed along bottom edge of lightguide with angular emittance set using distribution below
- German Master's student did angular CCD scan and Geant4 simulations on emittance angles of single/multiclad lightguides, scintillating fibers and WLS
- Scanned Theta angle from 0-90 deg; intensity weighted at each point by the 2pi azimuthal solid angle
- http://web.physik.rwth-aachen.de/~hebbeker/theses/nieswand_master.pdf
- Numerical aperture of our fibers: 0.555 -> Max angle for meridional rays: $\sin^{-1}(NA) = 33.7^{o}$
- Distribution not exact for our fibers but approximate to first order

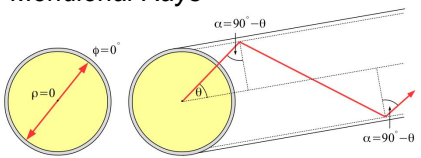
Beyond numerical aperture, only skew rays remain.

Higher angles -> rays closer to cladding

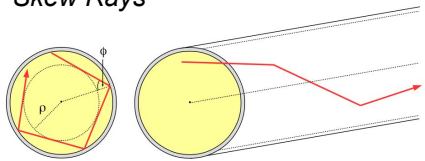


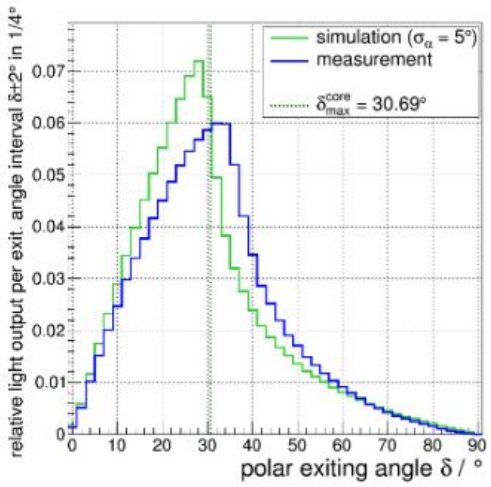
2 Types of Rays in Fibers:

Meridional Rays

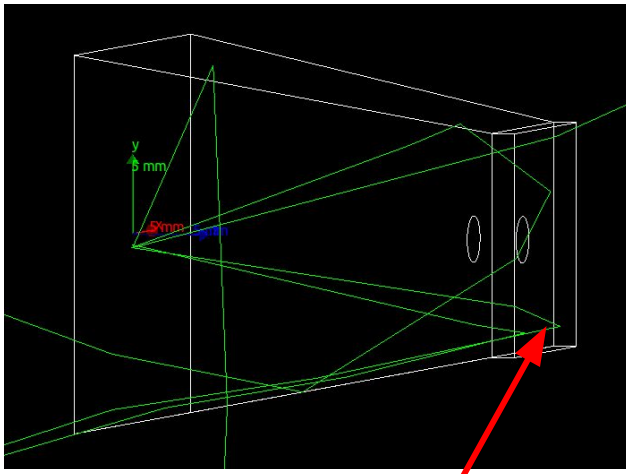


Skew Rays



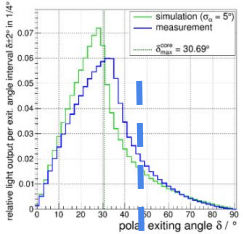


Lightguide 0: sPHENIX acrylic lightguide w/ detection volume as entire end

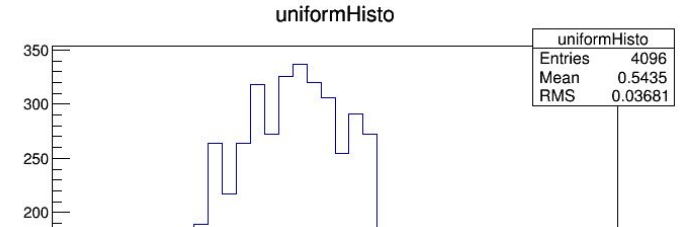


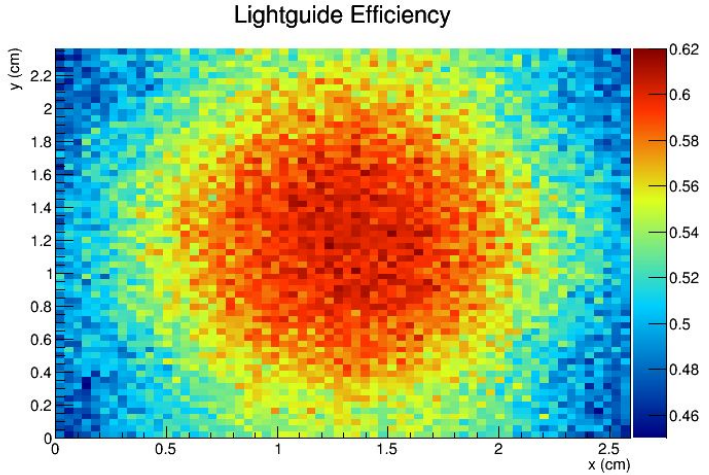
Detection volume

- Uniformity RMS:
  - 0.037 (% efficiency)
- Total Efficiency: 54.4%
- Sean measured ~70% in lab for this setup
- If you omit tracks > ~45 deg, simulation matches measurement

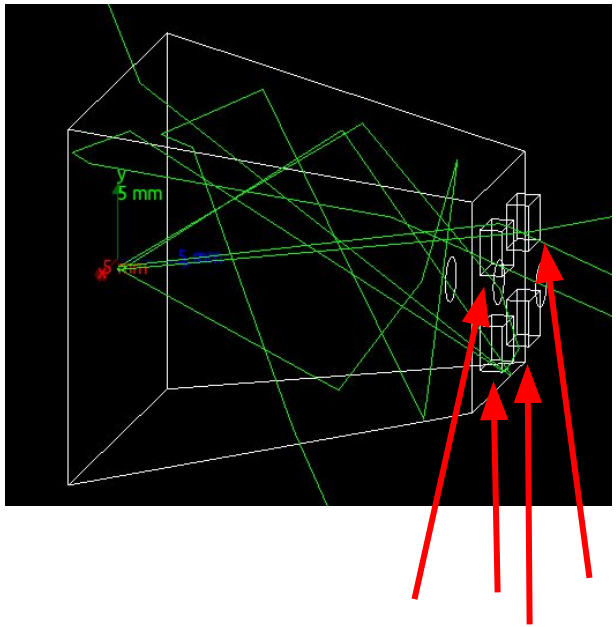


- Theories:
  - Cladding damage decreases number of high angle tracks
  - High angle tracks lost due to reflection off optical grease/PMT



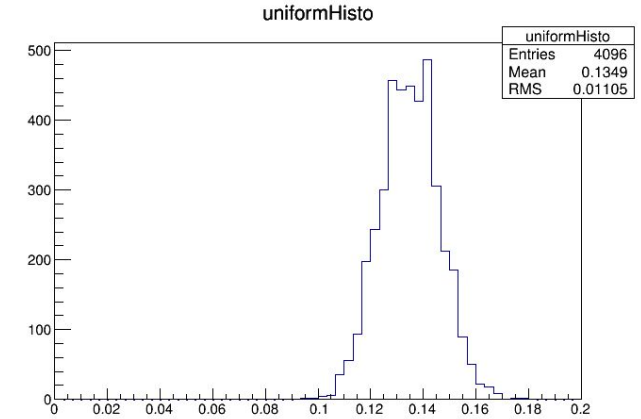


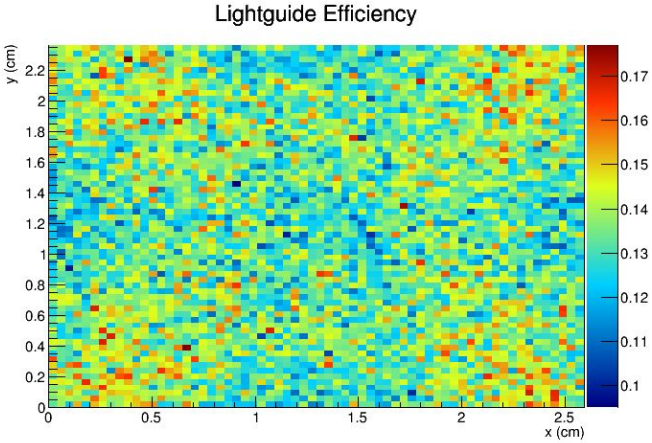
Lightguide 1: sPHENIX acrylic lightguide w/ 4 SiPMs per lightguide and a stainless steel screw in center



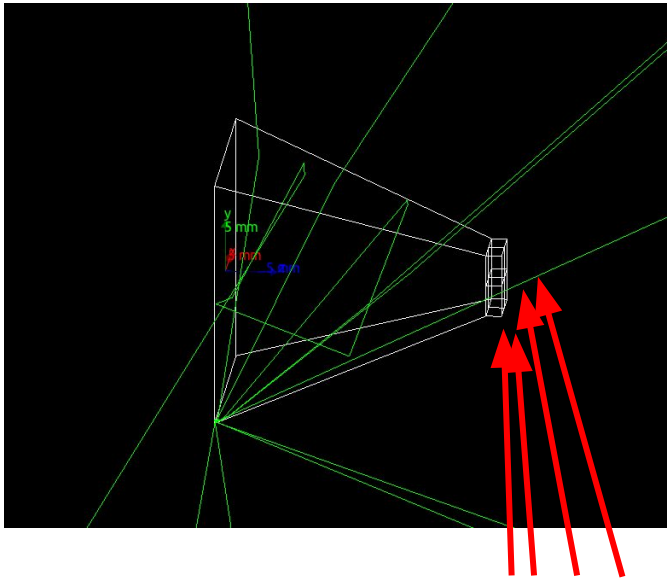
Detection volumes

- **Currrent sPHENIX LG**
- Uniformity RMS:
  - 0.011 (% efficiency)
- Total Efficiency: 13.5%
- Geometric acceptance:
  - 18.4% of LG0
  - 4 SiPMs (3x3 mm^2) = 36 mm^2
  - LG end(14x14 mm^2) = 196 mm^2
  - 18.4% of 54.4% -> efficiency of ~10.0%
- Efficiency and uniformity appear ~ maximally optimized for this acceptance size/lightguide design



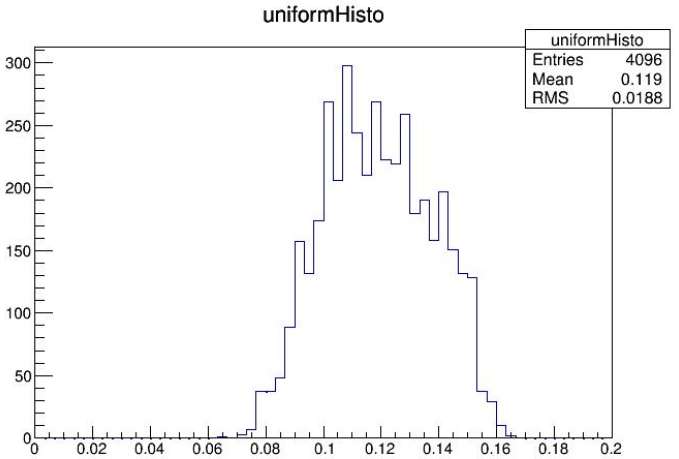


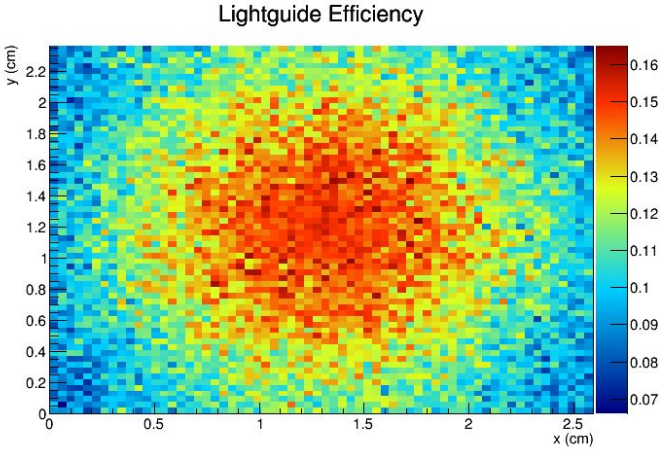
Lightguide 2: Original lightguide with no screw and no space b/w sipms (no mechanical connection)



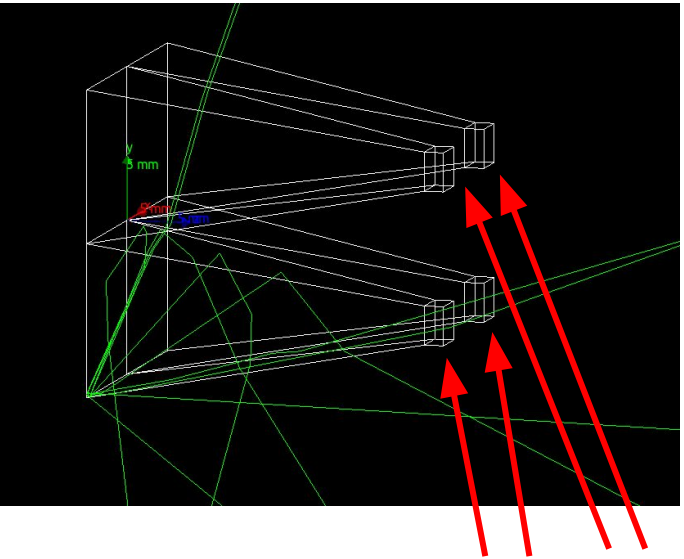
Detection volumes

- Uniformity RMS:
  - 0.0188 (% efficiency)
- Total Efficiency:
  - 11.9%
- Similar to LG0, 4 sipms bunched together causes uniformity distortion
- Total efficiency decreases as well -> increased slope causes lower efficiency along edges



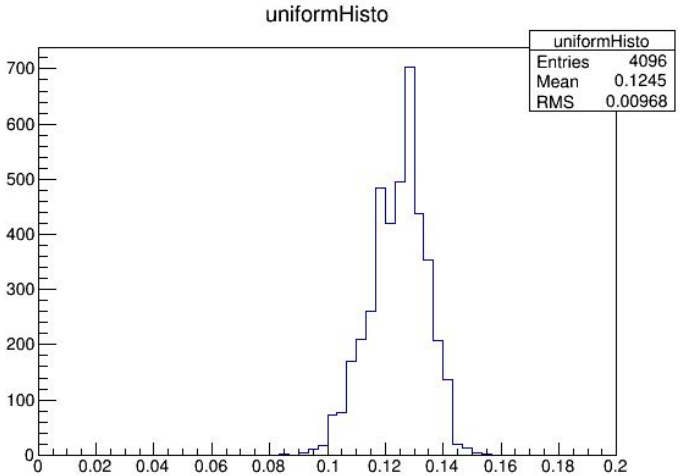


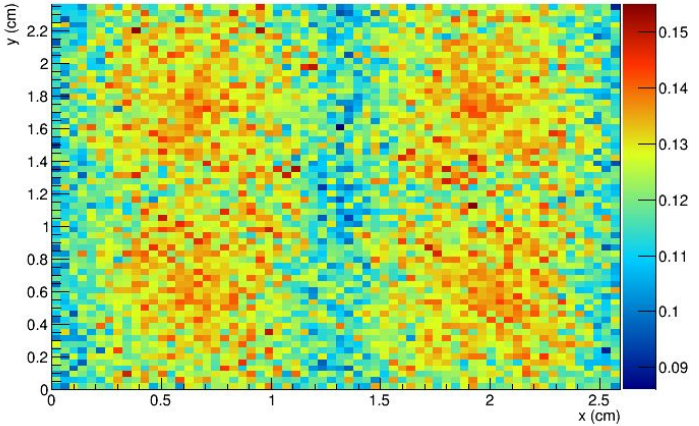
Lightguide 3: One acrylic lightguide per sipm (no mechanical connection)



Detection volumes

- Uniformity RMS:
  - 0.00968 (% Efficiency)
- Total Efficiency: 12.45%
- Evolution of LG2. Periodic non-uniformities still visible

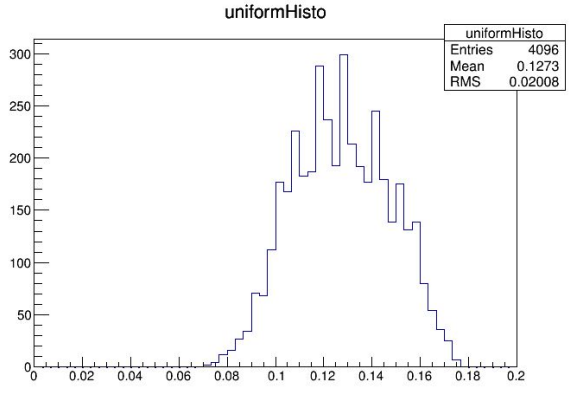


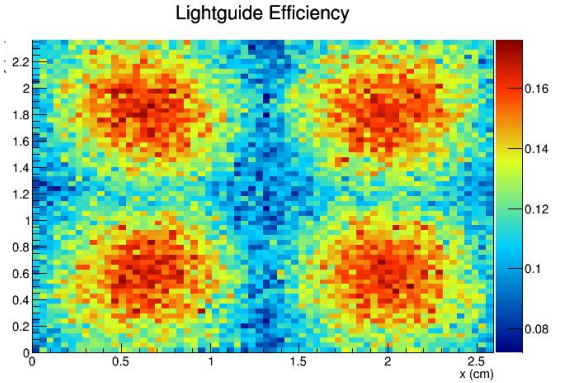


Lightguide 3: Short and Long (no mechanical connection)

Short Lightguide (1.34 cm): ½ height of LG3

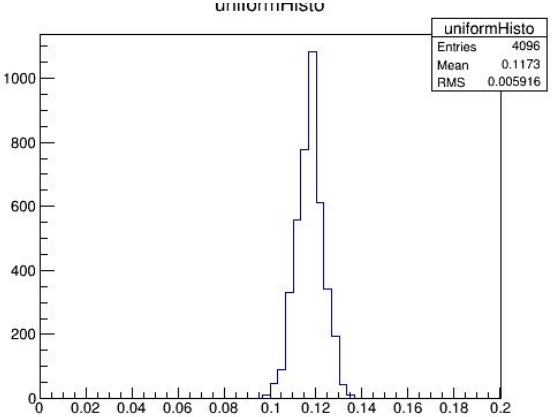
- Uniformity RMS:
  - 0.02 (% efficiency)
- Total Efficiency:
  - 12.7%

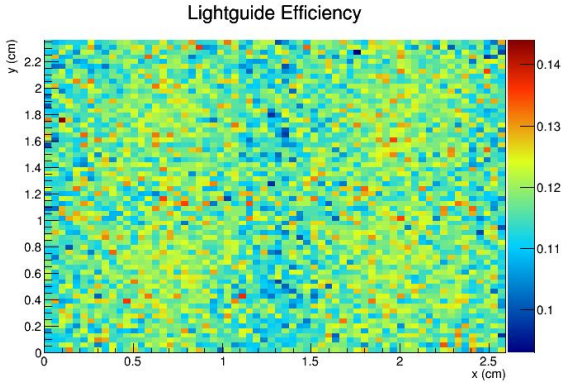




Long Lightguide (5.214 cm): 2x height of LG3

- Uniformity RMS:
  - 0.0059 (% efficiency)
- Total Efficiency:
  - 11.7%
- Efficiency/uniformity a function of slope of lightguide
- Periodic non-uniformities decreased by increasing length (increasing slope)





Conclusions

- Nominal lightguide design (LG1) achieves best mix of efficiency and uniformity
- Efficiency of 13.5% still very low
- Solutions:
  - Larger (or more) sipms
  - Mylar/paint on LG to improve reflectivity (needs to be simulated still)
  - Alternative lightguide designs